J. A. Marsh
Ser # 717

INSTRUCTION BOOK

FOR

MODEL 97 A
DC VOLTMETER-AMPLIFIER

Boonton ELECTRONICS Corp.
MORRIS PLAINS, NEW JERSEY

MP MASTER
MA25187

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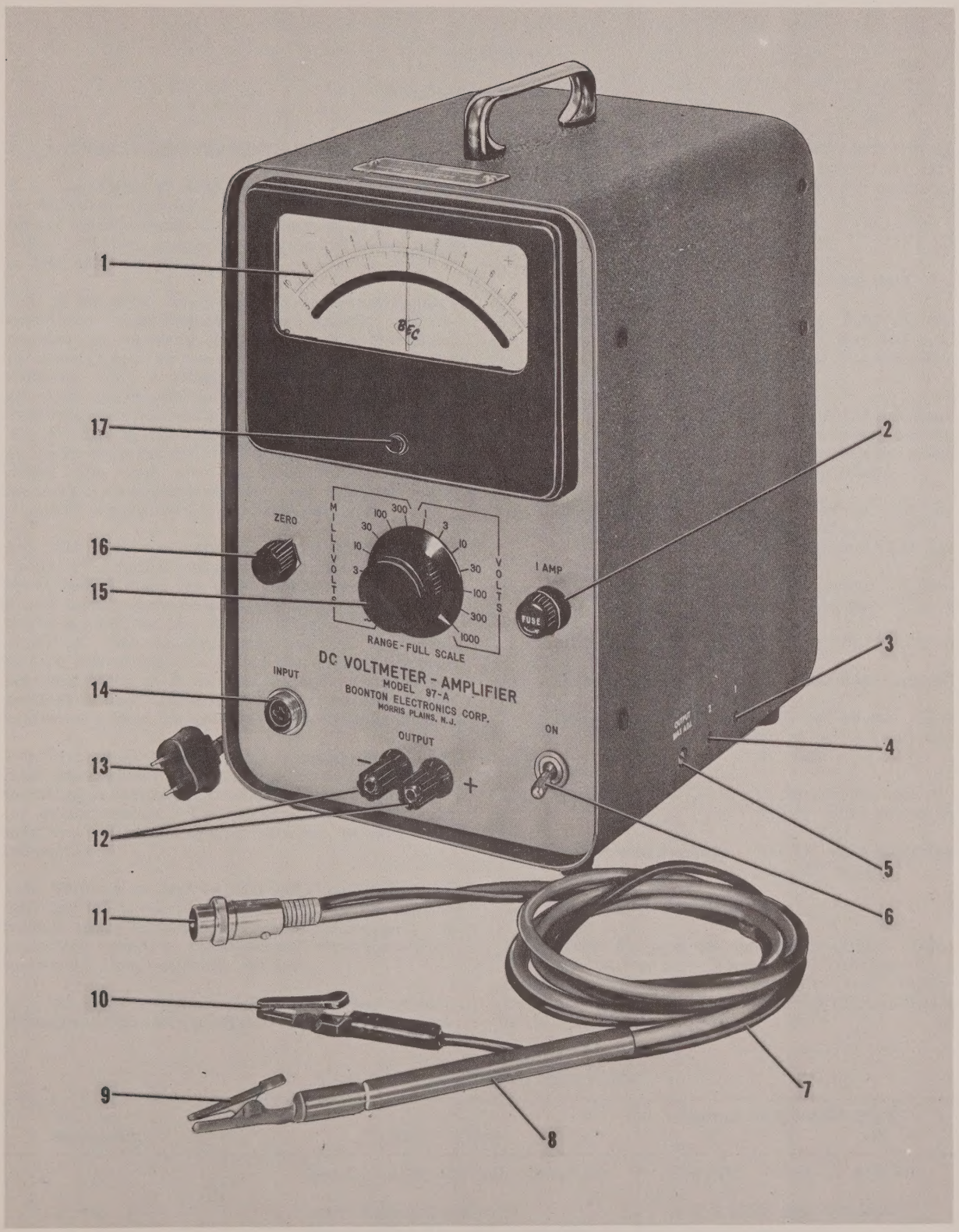

Figure 1-1. DC Voltmeter-Amplifier Model 97-A

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SECTION I

GENERAL DESCRIPTION

1-1. GENERAL DESCRIPTION. (See figure 1-1.)

1-2. The Model 97-A DC Voltmeter-Amplifier is a combination voltmeter and amplifier. It is designed for d-c measurements over the range of 10 uv to 1000 volts. Fourteen ranges cover from 300 uv full scale to 1000 volts full scale.

1-3. A six-inch, direct-reading, zero-center, mirrored meter scale indicates voltage polarity, and eliminates the necessity of reversing meter test leads, or of using a polarity reversing switch when measuring voltages. This is achieved through the use of a synchronous output rectifier consisting of a transistor switching circuit driven in phase with the input chopper. The arrangement provides the proper polarity indication on the panel meter. It also completely isolates output from input, thus eliminating the undesirable feedback often encountered when both input and output choppers are enclosed in the same envelope.

1-4. The high-input impedance of the Model 97-A DC Voltmeter-Amplifier is achieved by means of special break-before-make, low noise chopper circuitry, plus a high input impedance voltage divider. The chopper output is amplified by a stable, high-gain feedback a-c amplifier, then synchronously rectified to provide voltage indications of a magnitude and polarity proportional to those of the test voltage. Thus the exceptionally high degree of stability of the Model 97-A is attained without the use of d-c amplification stages.

1-5. D-c output binding posts mounted on the unit front panel permit interconnection and operation of indicating or control devices such as relays or recording milliammeters. The output at the binding posts may be used simultaneously with the meter without interaction.

1-6. Voltages as high as 1500 volts may be accidentally applied to the Model 97-A input without causing damage to the equipment and with rapid recovery. A protective circuit at the attenuator output guards the instrument from accidental overload.

1-7. As a d-c amplifier the Model 97-A has a maximum gain of 70 DB and is capable of providing ±0.5 ma into a 1500-ohm load. An output bias control in the instrument allows the adjustment of output to any current between 0 and 0.6 ma, with zero d-c input condition.

1-8. TECHNICAL CHARACTERISTICS.

Measurement . . .	10 uv to 1000 volts
Full Scale Ranges .	.3, 1.0, 3.0, 10, 30, 100, 300 mv; and 1.0, 3.0, 10, 30, 100, 300, 1000 V
Accuracy	3.0 percent of full scale on 1.0 mv range and up; 4.0 percent of full scale on 0.3 mv range
Input Impedance . .	100 megohms, 10 mv range and up; 30 megohms, 3.0 mv range; 10 megohms, 0.3 and 1.0 mv ranges
Maximum Amplifier Gain . . .	approx 70 db
Output Impedance	1200 ohms (approx)
Output Capability (Min).	±0.5 ma across 1500 ohms, or ±1.0 volt with no load
Zero Drift	10 microvolts, approximately (after warmup)
Power Requirements .	100-130 volts, 60 cycles only, 30 watts

1-9. LEADING PARTICULARS.

1-10. Table 1-1 lists the equipment supplied. Table 1-2 lists the tube complement of DC Voltmeter-Amplifier Model 97-A. Tables 1-3 and 1-4 list, respectively, the fuse complement and the chopper complement of the voltmeter-amplifier.

TABLE 1-1. EQUIPMENT SUPPLIED

No. Per Equipment	Name of Unit	Overall Dimensions (Max) H	W	D
1	Model 97-A DC Voltmeter-Amplifier	12-1/4 in.	7-1/8 in.	9-3/8 in.
1	Input Cable Assembly - Red alligator clip may be removed to allow use of phone tip.	57-1/2 in. lg (approximately)		

TABLE 1-2. ELECTRON TUBE COMPLEMENT

No. Per Equipment	Tube Designation	Type	Function
1	V1	12AX7	Amplifier
1	V2	6AU6	Amplifier
1	V3	12AT7	Amplifier-Cathode Follower
1	V4	6X4	Rectifier
1	V5	OA2	Voltage Regulator

TABLE 1-3. FUSE COMPLEMENT

Fuse Rating	--------	AGC 1.0 ampere

TABLE 1-4. CHOPPER COMPLEMENT

Mechanical Chopper Rating	--------	0-1-1/2 volts, dc, 1.0 ma
Transistor Chopper Type	--------	2N34

SECTION II

OPERATING PROCEDURES

2-1. GENERAL.

2-2. This section describes in detail the operating procedure for Model 97-A DC Voltmeter-Amplifier. All information required for safe and proper operation of the instrument is included. Be sure to read this section before placing the instrument into operation.

2-3. INITIAL TURN-ON PROCEDURE AND TESTS.

2-4. TESTS. To perform the initial tests proceed as follows.

a. After unpacking the unit, and before plugging it into an a-c outlet for the first time, turn the instrument back and forth several times to make sure the tubes have not fallen from their sockets due to rough handling.

b. Observe the meter pointer to see that it moves freely and rests at zero when the instrument is steady.

c. If the pointer rests to the right or left of zero, set it at zero with the zero setscrew. (See figure 1-1.)

CAUTION

Before plugging the instrument into the convenience outlet, make sure the power supply is 100-130 volts ac, 60 cycles.

2-5. TURN-ON PROCEDURE. To perform the initial turn-on procedure proceed as follows.

a. Plug the instrument into the power source.

b. Set ON toggle switch to ON (up), and allow a warm-up period of approximately one minute.

c. Connect the input cable assembly to the instrument and short together the black and red alligator clips.

d. Set the range switch/attenuator to the desired measuring range, and adjust the ZERO control to set the meter pointer at zero center.

NOTE

Whenever measuring ranges are changed, the above zeroing procedure should be followed. In general, however, the zero will not require resetting when switching to any range between 30 millivolts and 1000 volts full scale.

2-6. OPERATING PRECAUTIONS.

2-7. The Model 97-A DC Voltmeter-Amplifier is provided with a special overload circuit which permits accidental application of as much as 1500 volts to the meter input even on the most sensitive range without damage to the instrument. However, DO NOT EXCEED 1500 VOLTS PEAK INPUT UNDER ANY CIRCUMSTANCE.

NOTE

When the instrument has not been turned on for several hours during very humid weather, it may be desirable to allow a one-hour warm-up (to drive off accumulated moisture) before making measurements.

2-8. UNWANTED METER INDICATIONS.

2-9. In an instrument capable of indicating an input signal as small as a few microvolts, several sources of unwanted meter indications are of importance. One of the most troublesome of these is hum pickup. This may often make high-impedance measurements difficult if not impossible. A built-in hum rejection filter in the instrument reduces these hum pickup effects by approximately 60 db.

2-10. Other effects that may produce unwanted signal voltages are as follows.

a. Thermocouple junctions (heat effects).

b. Galvanic action (battery effect).

c. Photosensitivity (particularly of semiconductor devices).

d. Amplifier noise (due to noisy components, microphonic tubes, and tube noise).

2-11. In using the voltmeter-amplifier observe the normal precautions that apply when using any type of voltmeter. For example, when measuring unknown values of voltage, always set the range switch/attenuator to the highest range, then decrease the setting to the proper range.

2-12. USE AS AN AMPLIFIER.

2-13. If the instrument is used as an amplifier, the signal output is taken from the OUTPUT terminals on the front panel. These are coupled to the output of a cathode follower and to a biasing resistance.

SECTION III

THEORY OF OPERATION

3-1. GENERAL.

3-2. A simplified block diagram of the Model 97-A Voltmeter-Amplifier circuit is shown in figure 3-1. The circuit consists of an input attenuator; a filter circuit to reduce the effect of 60-cycle hum pickup; an overload protector which limits the voltage applied to the chopper; a chopper which converts the applied dc to 60 cps ac; four feedback amplifier stages; a transistorized chopper circuit that reconverts the amplified ac to dc; a zero-center d-c voltmeter calibrated in volts and millivolts; a cathode follower output circuit; and a d-c power supply source.

3-3. DETAILED CIRCUIT DESCRIPTION.

3-4. RANGE SWITCH/ATTENUATOR. The input d-c voltage is applied directly to the range switch/atten-

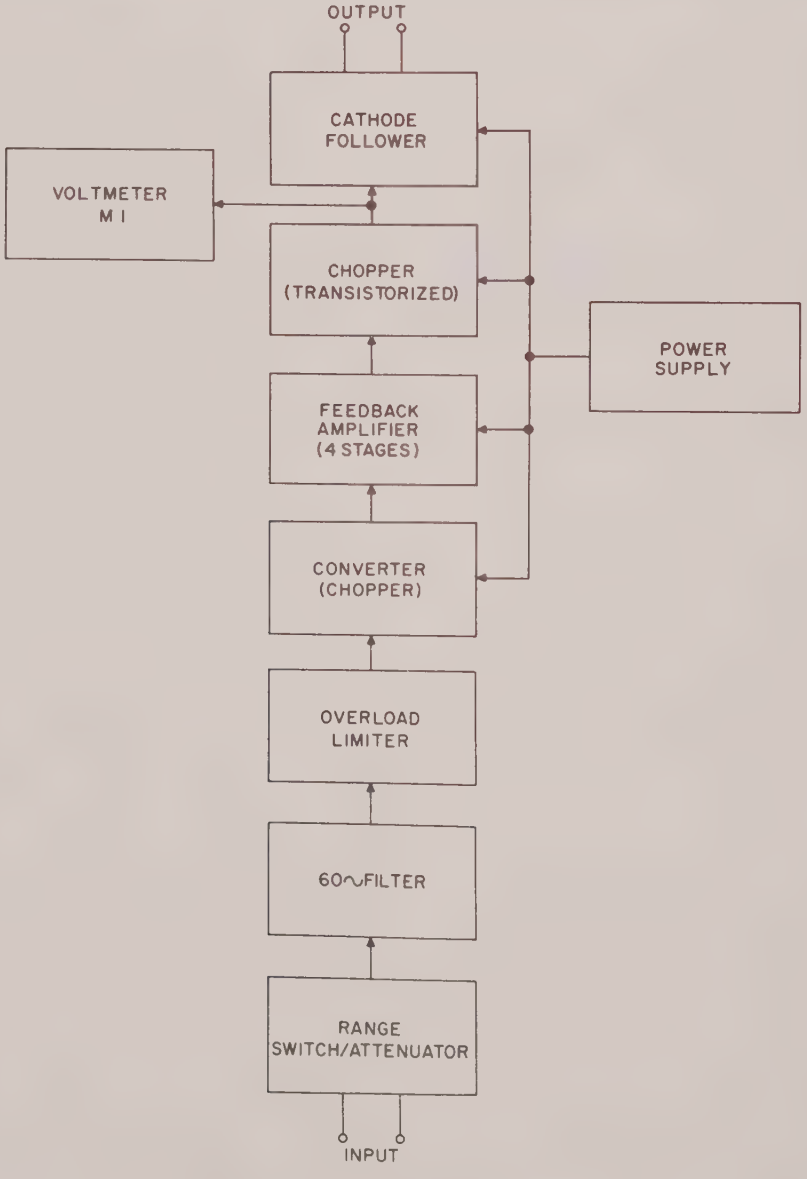


Figure 3-1. Simplified Block Diagram

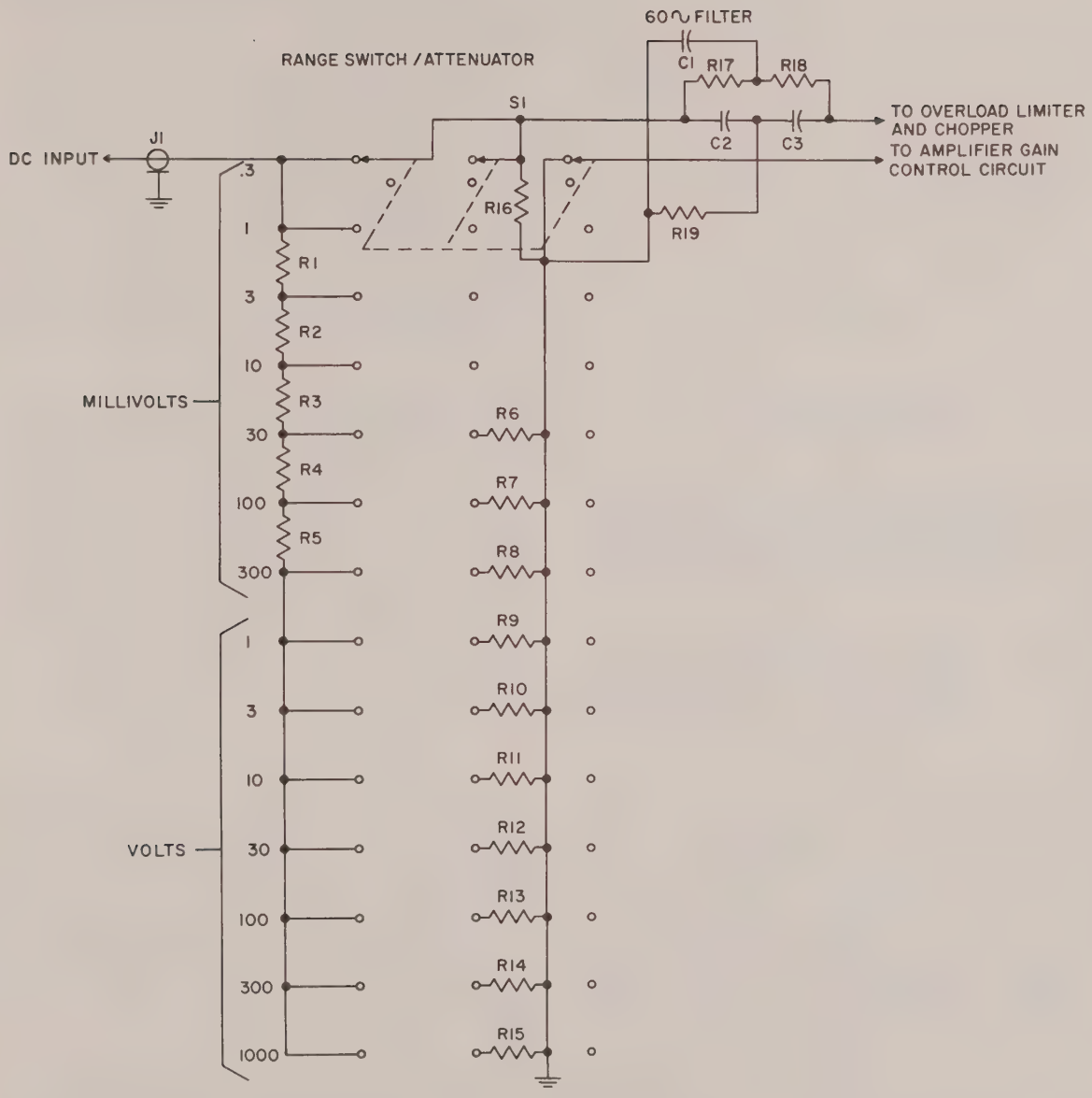


Figure 3-2. Range Switch/Attenuator and 60-Cycle Filter Schematic Diagram

uator circuit (see figure 3-2), which couples the signal directly through the 60-cycle filter consisting of R17, R18, and R19, C1, C2, and C3, to chopper CH1 when the range switch is set to either the .3 MILLIVOLTS or the 1 MILLIVOLTS position. In either of these positions the input impedance is 10 megohms (composed of R16 in parallel with the total effective resistance of V1A input circuit). The change in sensitivity when switching from the 0.3 millivolt to the 1.0 millivolt range, and vice versa, is accomplished by a change in the amplifier gain. Thereafter, the range switch changes the sensitivity of the other twelve ranges (3.0 millivolts to 1000 volts) by switching precision resistors into position, thereby attenuating the input signal to 1.0 millivolt.

3-5. 60-CYCLE FILTER. A 60-cycle filter (figure 3-2) is shown coupled to the range switch/attenuator output. The filter is of the bridge-tee type and provides approximately 60 db of attenuation. This filters out any stray 60-cycle components that might be present at the unit input.

3-6. OVERLOAD LIMITER. A simplified schematic

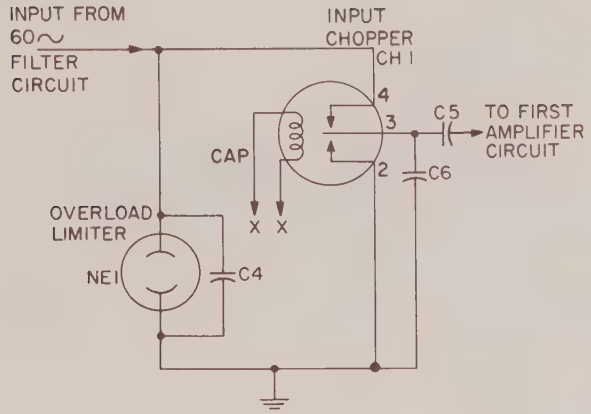


Figure 3-3. Overload Limiter and Chopper Schematic Diagram

diagram of the overload limiter and chopper circuits is shown in figure 3-3. The overload limiter circuit consists of a neon lamp which limits the voltage applied to the chopper circuits to approximately 50 volts, even though the input voltage may be as high as 1500 volts.

3-7. INPUT CHOPPER (CONVERTER). The Model 97-A input chopper circuit is shown schematically in figure 3-3. Its function is to convert the applied dc to 60-cycle ac. The input chopper is a low-noise, 60-cycle resonant type, the contacts of which are adjusted for break-before-make. The a-c chopper output is applied through coupling capacitor C5 to the grid of the first amplifier tube.

3-8. AMPLIFIER CIRCUIT. The instrument amplifier circuit (figure 3-4) provides four stages of a-c amplification. The first two stages utilize a low-noise, non-microphonic double triode (V1) in a degenerative feedback circuit. The input ac from the chopper circuit is applied to the grid of the first amplifier tube (V1A) through coupling capacitor C5. The inverted, amplified voltage is fed to tube V1B through capacitor C8. A portion of the output of tube V1B is fed back to V1A through the degenerative feedback network comprising capacitor C11 and resistor R26. V1B output is also fed to the grid of the next amplifier stage through coupling capacitor C12.

3-9. The third amplifier stage employs a high-gain pentode (V2) with two gain controls in the cathode circuit which are switched by means of the range switch. This arrangement provides a means of adjusting sensitivity of the two most sensitive ranges (0.3 and 1.0 millivolt) of the instrument. The a-c voltage appearing at the grid of the third amplifier tube is amplified and fed to the fourth stage through coupling capacitor C16. The amplifier output stage consists of one-half of double triode V3. The voltage appearing at the plate is fed back, degeneratively, through R34 to the cathode of the third amplifier stage (V2) to improve stabilization.

3-10. OUTPUT CHOPPER (TRANSISTORIZED). The

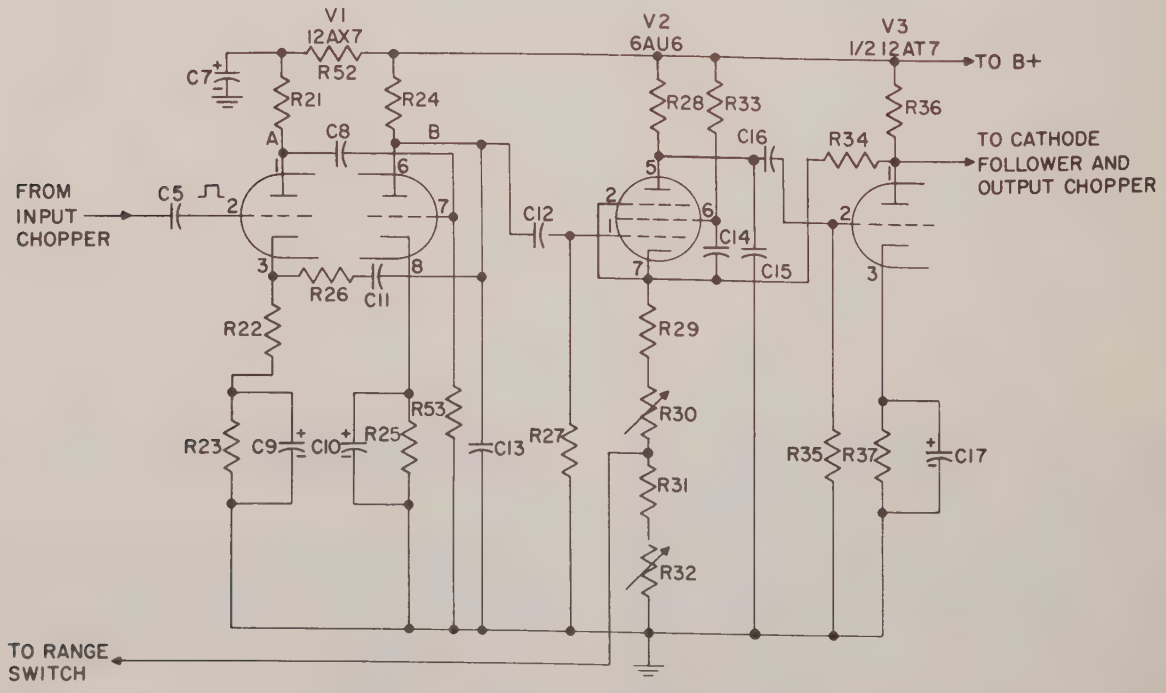


Figure 3-4. Amplifier Circuit Schematic Diagram

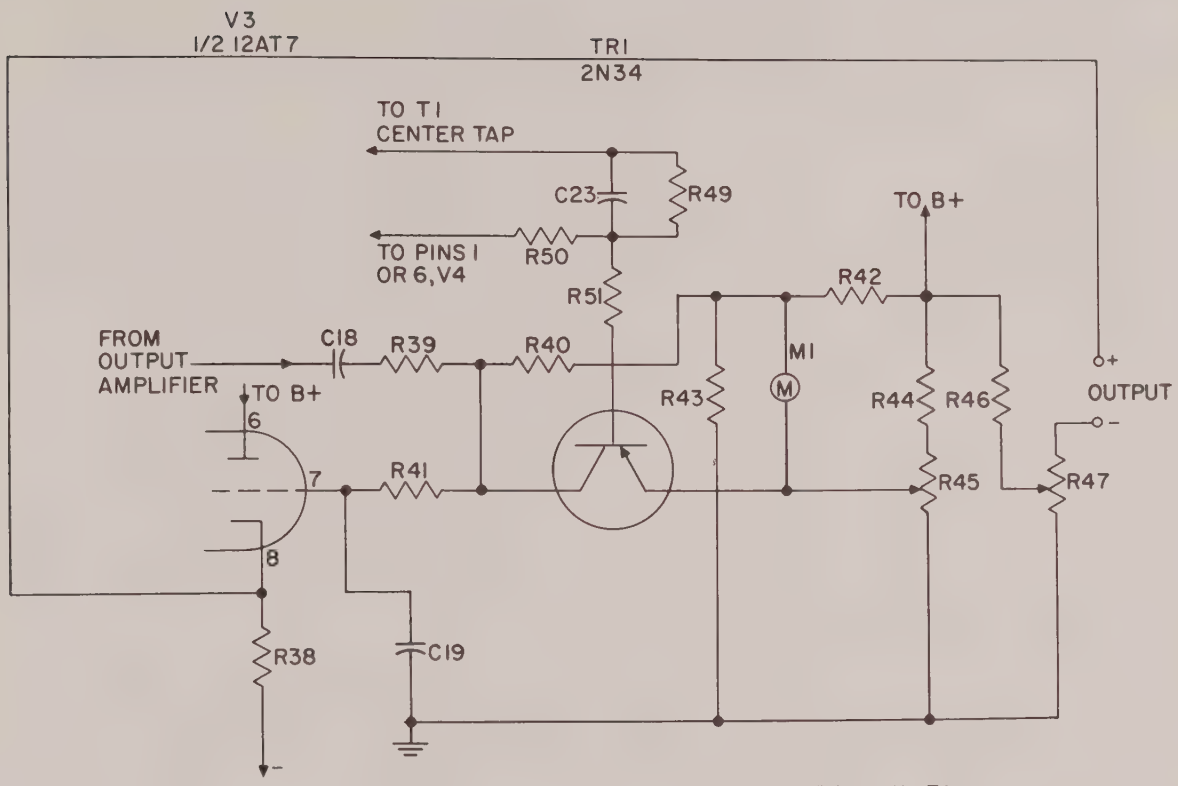


Figure 3-5. Output Chopper, Meter, and Cathode Follower Schematic Diagram

function of the output chopper (figure 3-5) is to rectify the a-c voltage at the output of the fourth amplifier stage, (V3A). The rectified output is such that its polarity is identical to that of the input voltage being measured. For this function transistor TR1 is connected to the output amplifier through coupling capacitor C18 and limiting resistor R39. The chopper output is connected to the meter circuit consisting of the meter, M1, associated series resistor R40, and bias resistors R42 through R45. R45 is the meter zeroing control.

3-11. CATHODE FOLLOWER. The pulsating dc from output chopper TR1 is coupled to the grid of cathode follower V3B through a smoothing filter comprising R41 and C19, (see figure 3-5). The output of V3B is connected to the front panel binding posts (OUTPUT), providing a d-c output with polarity and magnitude proportional to the d-c input. Bias control R47 applies a variable bias voltage to the - OUTPUT binding post, and is used to provide biasing for external indicators.

3-12. POWER SUPPLY. The power supply (see figure 4-11) is a conventional full-wave rectifier circuit incorporating voltage regulation for the high-voltage supply. The output of rectifier V4 is coupled through the pi-type filter comprising L1, C20, C21, and series resistor R48 to voltage regulator V5. The 150-volt d-c regulated output is then connected to the amplifier stages and cathode follower through plug P2.

3-13. A low voltage d-c supply comprising selenium bridge rectifier CR1 and filter capacitor C22 supplies d-c heater voltage to the heaters of amplifiers V1 and V2. The driving voltage for transistor chopper TR1 is obtained from an attenuating-phasing network composed of resistors R49, R50, and R51, and capacitor C23. The input to this network is taken from one side of the high-voltage winding of power transformer T1.

SECTION IV

MAINTENANCE

4-1. PRECAUTIONS.

4-2. When making voltage measurements in the process of maintenance or service, the range switch/attenuator shield should not be removed. Resistance and capacitance measurements may be performed with power off and shield removed.

4-3. Use care in removing components from the attenuator switch contacts. Contacts are easily broken, necessitating replacement of the entire switch wafer.

4-4. PREVENTIVE MAINTENANCE.

4-5. Other than keeping the instrument dry when stored, no preventive maintenance is required.

4-6. CORRECTIVE MAINTENANCE.

4-7. PRELIMINARY INSPECTION. Before starting trouble shooting, make the preliminary checks listed in table 4-1.

4-8. SYSTEM TROUBLE SHOOTING. Table 4-2 and figures 4-12 and 4-13 will be helpful in tracing the listed faults to a particular circuit and/or component.

4-9. REPAIR. The principal parts in the instrument subject to possible failure are the electrolytic capacitors, tubes, chopper, and the selenium rectifier.

4-10. Due to the very low signal level and high stage gain, components in the V1 (12AX7) circuit are more likely to develop unsatisfactory noise conditions, or to exhibit instability, than those components used where signal levels are higher.

4-11. Normal life of electrolytic capacitors should be 5 to 10 years, that of tubes somewhere between 5000 and 10000 hours of service.

4-12. The five tubes (V1, V2, V3, V4, and V5), the fuse (F1), and the meter lights (I1 and I2) are easily accessible (see figures 1-1 and 4-1). Instructions for removal, disassembly, reassembly and replacement of the components are included in the following paragraphs.

4-13. REMOVAL. To remove the panel assembly proceed as follows. (See figures 4-1 through 4-5 for location of components.)

a. Remove the four screws located at the front portion of the Model 97-A case assembly sides.

b. Remove the two screws at the back of the case assembly bottom.

c. Pull the panel assembly out slowly until the power supply, located at the top rear interior of the case, is readily accessible (see figure 4-1).

d. Pull out the power connector plug from the power supply socket, and remove the voltmeter and amplifier assembly.

4-14. To remove the power supply assembly, remove the four screws at the rear of the case assembly sides, and pull out the power supply assembly. Use care in pulling the power cord through the hole in the case assembly to prevent breaking the junction of cord and plug.

4-15. DISASSEMBLY. Two items of the panel assembly, the meter and the attenuator, may present difficulties in removal. For this reason, only the removal procedure for these two items will be detailed. For the remainder of the components, removal is obvious.

4-16. METER REMOVAL. To remove the meter, proceed as follows.

a. Remove the two hex nuts and flat washers which hold the terminal board on the meter terminals, and pull off the terminal board (see figure 4-1).

TABLE 4-1. PRELIMINARY INSPECTIONS

Item	Inspection
A-C Power Circuit	Faulty power cord or plug. Blown fuse (F1).
Electron Tubes	Proper operation in tube tester.
All Components	Visual damage. Moisture.
Electrical Connections	External evidence of broken or shorted connections (including test leads). Good solder joints.
Chopper	Listen for buzz.

TABLE 4-2. SYSTEM TROUBLE SHOOTING

SYMPTOM	PROBABLE CAUSE	REMEDY
No meter indication with input signal applied - Meter can be zeroed	Open 60-cycle filter	Replace defective component.
No meter indication with input signal applied - V1 and V2 not lit (or very dim)	Defective selenium rectifier	Check forward and back resistances and replace if defective (d-c output should be approximately 12 volts with a-c ripple of 0.3 volts).
	V1 or V2 heater open	Replace V1 or V2 as required.
No meter indication with input signal applied - ZERO Control ineffective	B+ not being supplied by power supply	Check V4 (6X4), L1, or R48, and replace defective component to restore B+ supply.
Incorrect meter readings on one or more ranges	Defective voltage divider resistor	Check as listed below and replace defective component

Readings Correct On: (Ranges)	Readings Incorrect On: (Ranges)	Defective Resistors
0.3 and 1.0 mv	3.0 mv	R1
0.3, 1.0, and 3.0 mv	10 mv	R2
0.3, 1.0, 3.0, and 10 mv	30 mv	R3 or R6
0.3, 1.0, 3.0, 10, and 30 mv	100 mv	R4 or R7
0.3, 1.0, 3.0, 10, 30, and 100 mv	300 mv	R5 or R8
All Millivolt Ranges	1.0 v	R9
All Millivolt Ranges	3.0 v	R10
All Millivolt Ranges	10 v	R11
All Millivolt Ranges	30 v	R12
All Millivolt Ranges	100 v	R13
All Millivolt Ranges	300 v	R14
All Millivolt Ranges	1000 v	R15

Abnormally high meter jitter	External noise pickup	Reduce external noise field if possible.
	Mechanical chopper (CHI) noise	Replace chopper.
	Microphonic or leaky tube V1 (12AX7)	Replace tube.
	Noisy components in V1 stage	Replace defective components.

TABLE 4-2. SYSTEM TROUBLE SHOOTING (continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Low meter readings on all ranges	Defective meter	Replace meter.

b. Remove the two lug-terminated leads from the meter terminals, noting the lead color coding for ease of replacement.

c. Remove the two meter lights, I1 and I2, by grasping the black bases and pulling out slowly. Ease of removal may be accomplished by sliding a thin screwdriver edge into the grooves of the light sockets, and spreading the groove edges slightly.

d. Remove the four hex nuts and lockwashers which secure the meter to the front panel, and remove the meter.

4-17. RANGE SWITCH/ATTENUATOR REMOVAL. To remove the range switch/attenuator proceed as follows.

NOTE

Normally the components mounted on the range switch/attenuator can be reached for testing or replacement without unsoldering the cables or leads into the component. It may, however, be necessary to remove the knob and hex nut holding the range switch/attenuator to the front panel to allow turning the switch assembly sufficiently to expose the part to be tested. If this becomes necessary, the removal procedure described below should be followed.

a. Remove the two hex nuts on the rear of the range switch/attenuator shield and carefully slide off the shield.

NOTE

For ease of shield removal, remove the chopper first.

b. Remove all the leads on the range switch/attenuator, and tag the leads for ease of reassembly.

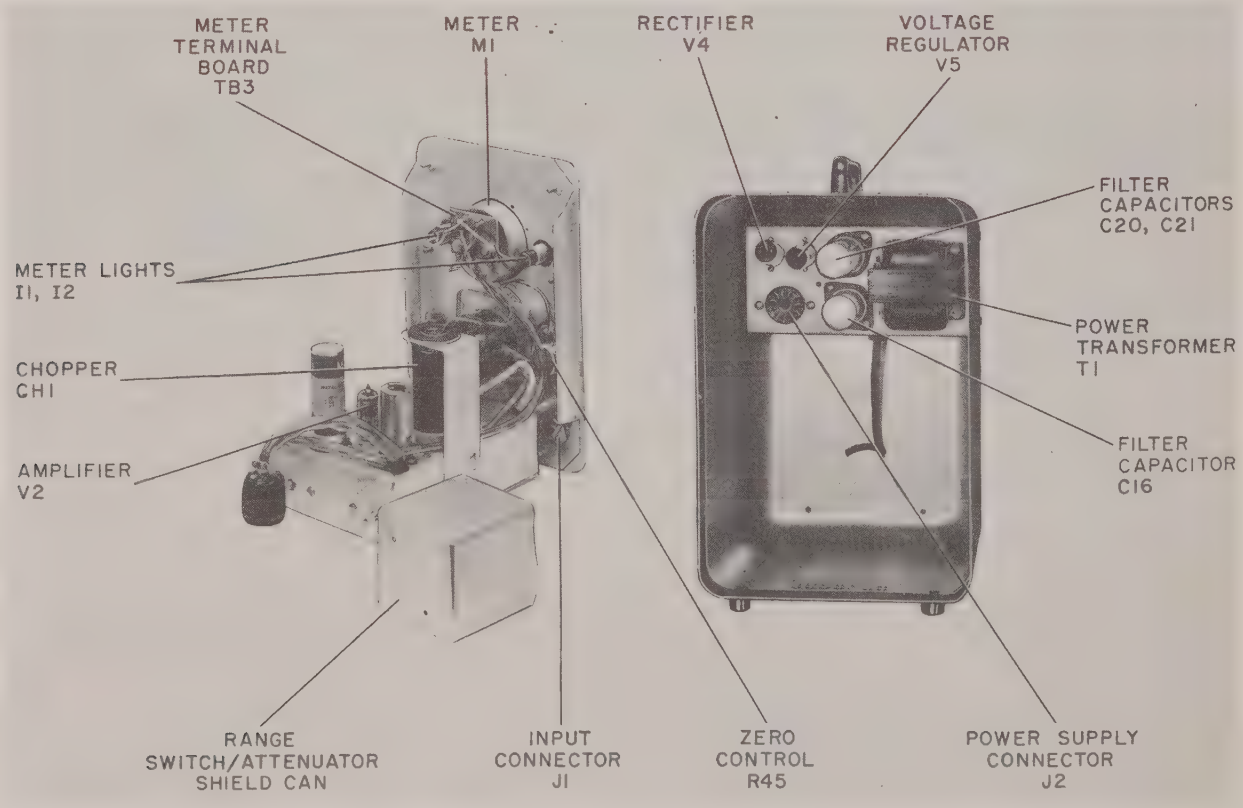


Figure 4-1. Interior View, Voltmeter-Amplifier Assembly Removed

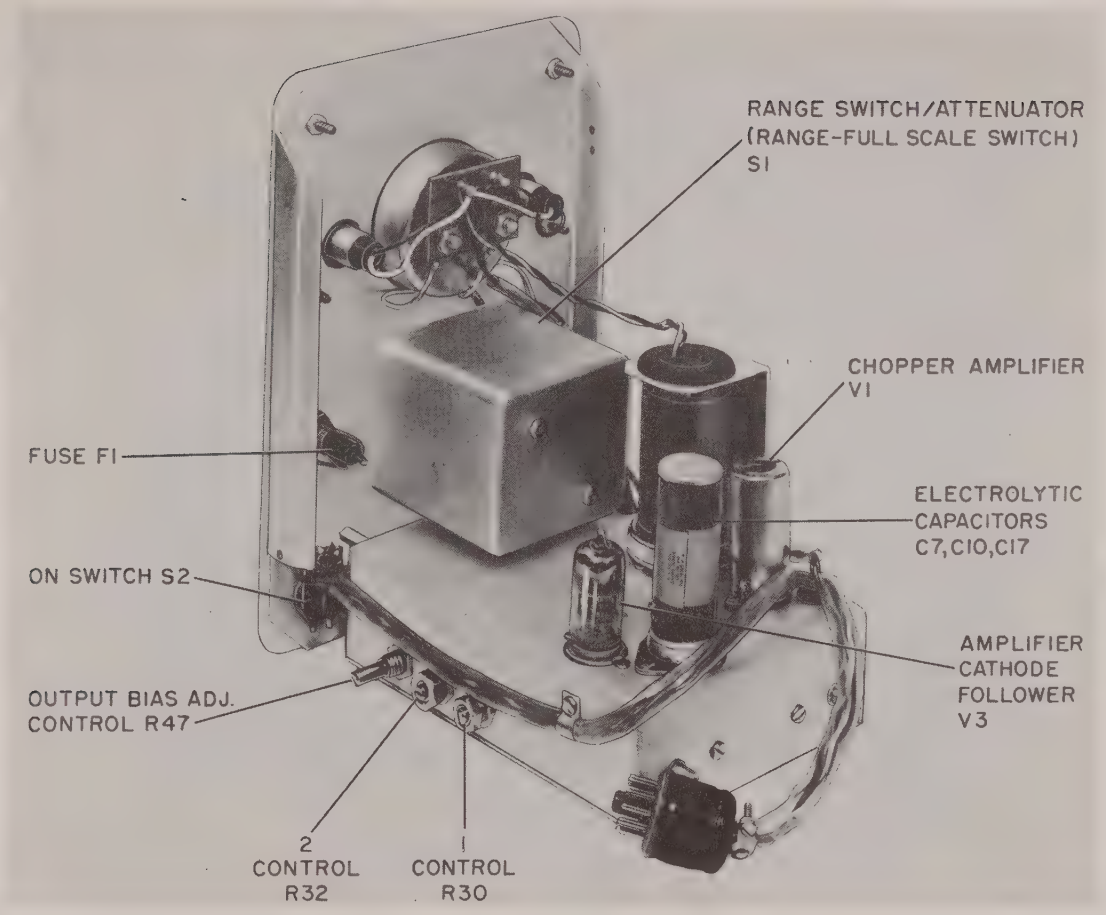


Figure 4-2. Voltmeter-Amplifier Assembly, Left Rear View

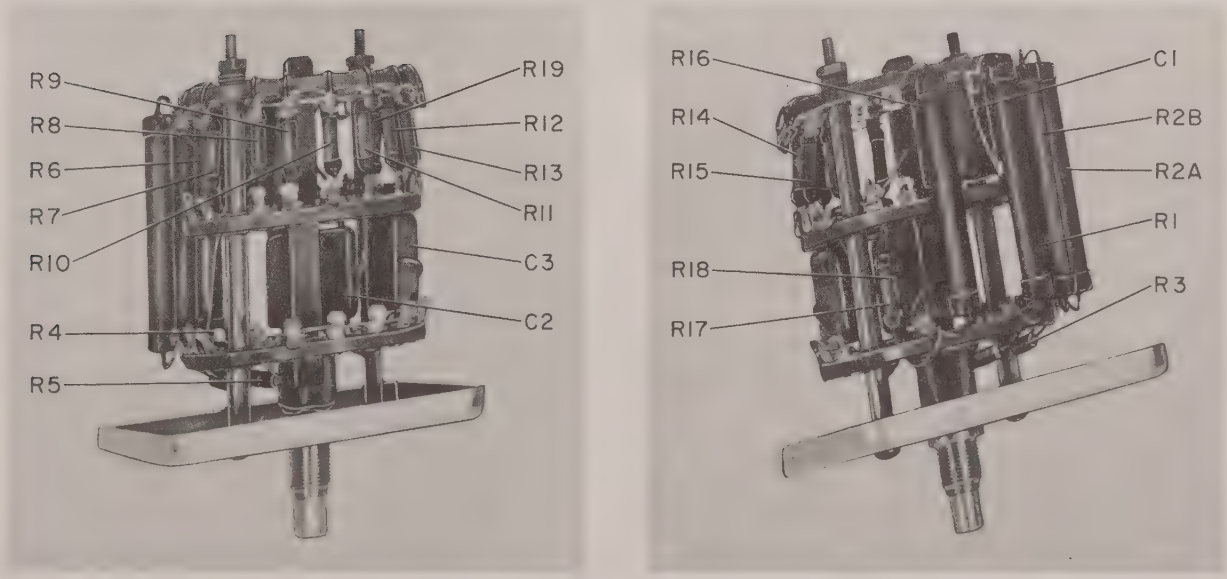


Figure 4-3. Range Switch/Attenuator

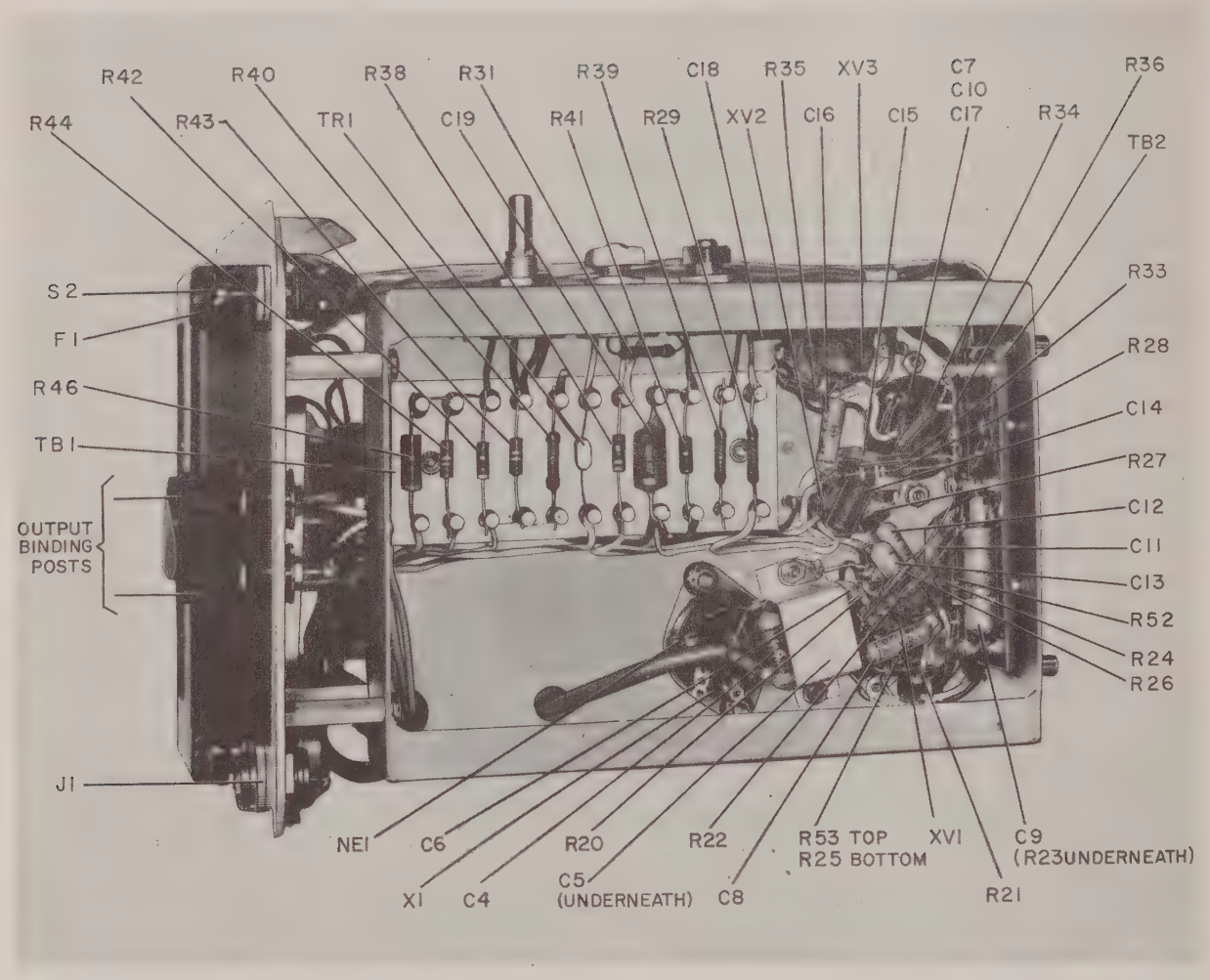


Figure 4-4. Voltmeter-Amplifier Assembly, Bottom View

c. Loosen the Allen set screws in the switch knob, and pull the knob off the shaft.

d. Remove the hex nut which secures the range switch/attenuator to the front panel, and pull the component out from the rear of the front panel. Use care in handling to avoid damage to the shaft, wafers, or contacts.

4-18. REASSEMBLY AND REPLACEMENT. Reassembly and replacement procedures are the reverse of the removal and disassembly procedures outlined in paragraphs 4-13 through 4-17.

4-19. If replacement of transistor chopper TR1 is necessary, be sure that the leads of the replacement unit are properly identified by their spacing (two leads close together, one lead further away) and then wired as shown in figure 4-6. Wrong connection can result in damage to the new replacement and/or associated components.

4-20. PHASING OF REPLACEMENT POWER TRANSFORMER (T1) LEADS. If it is necessary to replace power transformer T1, the procedure described below must be followed to insure correct operation of the instrument.

a. Connect primary, high-voltage, and 5.0-volt windings as on original transformer (one yellow lead goes to pin 3 of V4).

b. Temporarily connect the two green leads from the 6.3-volt winding to pins 3 and 4 of V4 (6X4).

c. Remove V4, and turn on the instrument. Tubes V1 and V2 should light normally and there should be approximately 12 volts dc between pins 10 and 11 of J2. If results are as expected, solder green leads permanently in place.

d. If V1 and V2 do not light normally, and approximately 2.0 volts dc appear between pins 10 and 11 of J2, turn off the power to the instrument and reverse the two green leads, soldering them permanently in place.

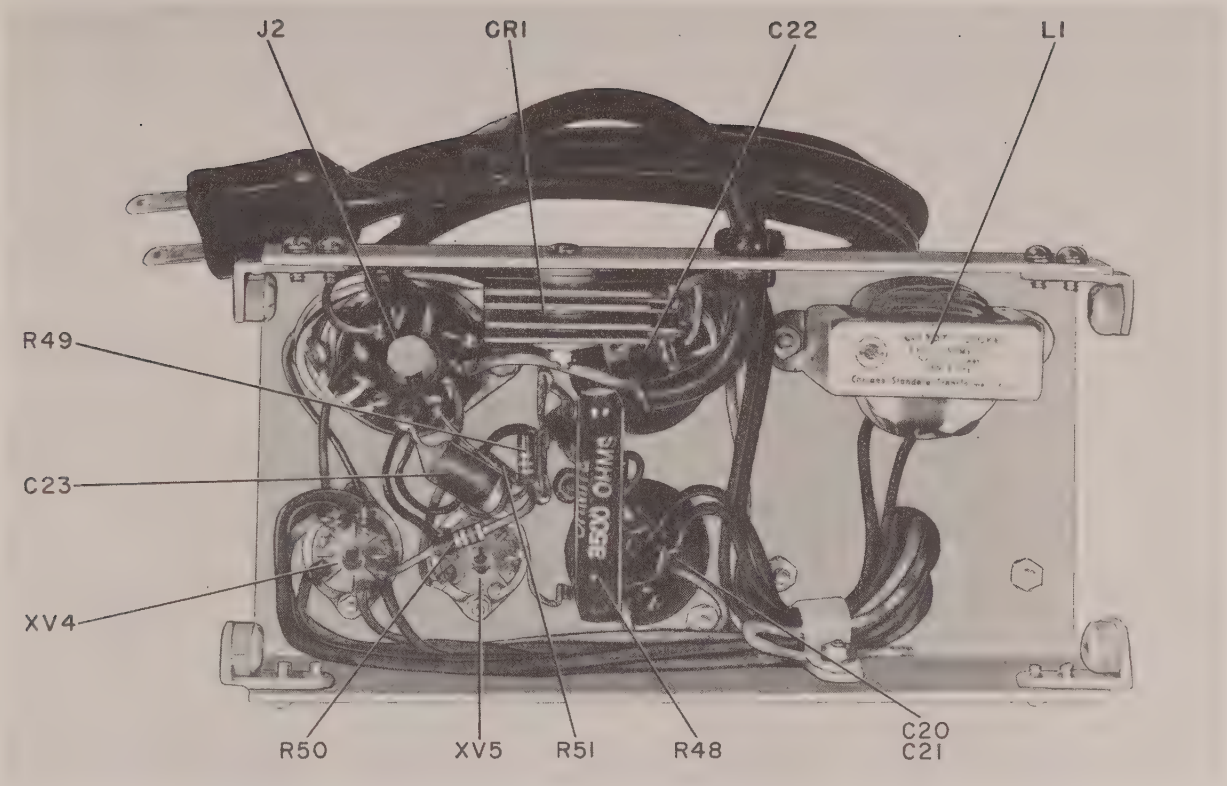


Figure 4-5. Power Supply, Bottom View

TABLE 4-3. TEST EQUIPMENT REQUIRED

Name and Description	AN or Mfr's Designation	Function
D-C voltage Calibrator (w/out-puts of 0.0003, 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1.0, 3.0, 10, 30, 100, 300, and 1000 v; provision for dividing any of seven lower voltages into five parts; accuracy ±0.7 percent)	-	Provide accurate voltages required for test procedures.
Variac	General Radio Model V-20M or equivalent	Provide accurate steps in input a-c line voltage for test procedures.
Resistor (20 megohm, 2.0 watts, 1.0 percent)	Aerovox CP-2 deposited carbon or equivalent	Check input impedance.
D-C Voltmeter (20000 ohms/volt, 0-2 volts range, 1.0 percent)	Hewlett Packard Model 410B or equivalent	Output tests.
Milliammeter (0-1.5 ma, 1500 ohms, 1.0 percent)	-	Output and drift tests.
SPST	-	Check input impedance.

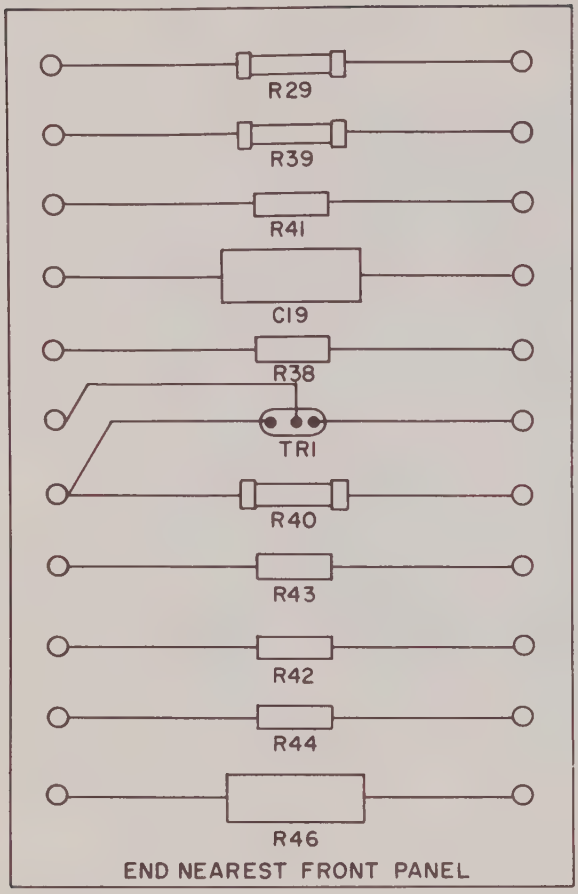


Figure 4-6. Transistor-Chopper TR1, Terminal Board Wiring

e. Replace V4 and turn on the instrument.
f. Connect the red probe clip to a positive (+) input voltage, and observe that the meter pointer swings to the right (+). If it swings to the left instead, turn off the instrument, and change the connection of resistor R50 to the opposite high-voltage pin (see figure 4-11). In other words, if R50 was connected to pin 1 of V4, change it to pin 6, and vice-versa. This will make a positive input voltage read in the correct direction (right) on the instrument meter.

4-21. TEST PROCEDURES.

4-22. The following paragraphs outline the various tests performed on the instrument either during a normal inspection or after a repair or replacement of a component (other than pilot light, fuse, or connector). Table 4-3 lists the equipment necessary to accomplish the testing.

4-23. ACCURACY TEST (117 V AC SUPPLY). To check the accuracy of the instrument proceed as follows.
a. Set up the equipment as shown in figure 4-7.
b. Turn power on to all equipment after adjusting variac output to 117 volts, and allow to stabilize for at least 30 minutes.
c. Set RANGE-FULL SCALE switch to 1000.
d. With zero output from d-c voltage calibrator, zero the Model 97-A using the ZERO control.
e. Apply 1000 volts from d-c voltage calibrator. Read and record voltage appearing on Model 97-A.
f. Reverse leads of d-c voltage calibrator output. Read and record voltage appearing on Model 97-A.
g. Repeat steps d through f for every position of the RANGE-FULL SCALE switch, using the corresponding output voltage from the d-c voltage calibrator. On the 1.0-millivolt to 1000-volt ranges the instrument should read within 3.0 percent of the applied voltage, while on the 0.3-millivolt range the accuracy should be 4.0 percent. Linearity may be checked on any convenient range by applying voltages equivalent to the major calibration points on the meter (i.e. 2, 4, 6, 8, 10) while noting the meter readings. Errors greater than 3.0 percent of full scale may indicate a defective meter movement.

4-24. VOLTMETER DRIFT TEST. To check voltmeter drift proceed as follows:
a. Set up the equipment as in figure 4-7.
b. Check the mechanical zero of the meter and reset if required.
c. Set RANGE-FULL SCALE switch to .3 MILLIVOLTS position. Connect input cable assembly to instrument and short black and red alligator clips together.

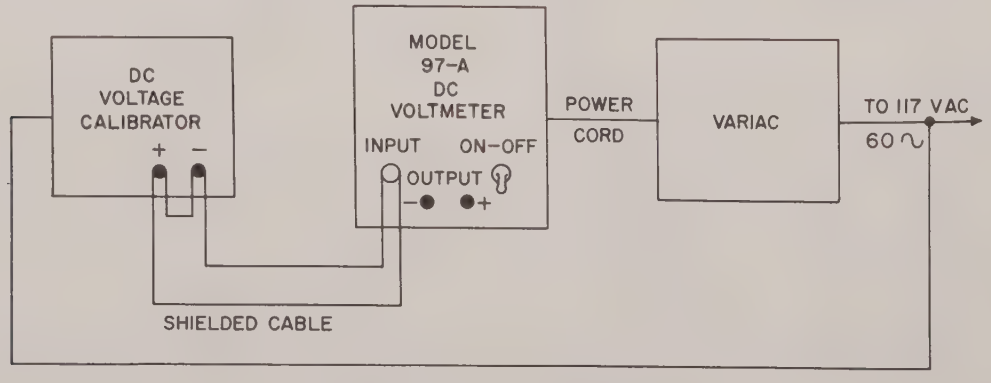


Figure 4-7. Accuracy Test Setup

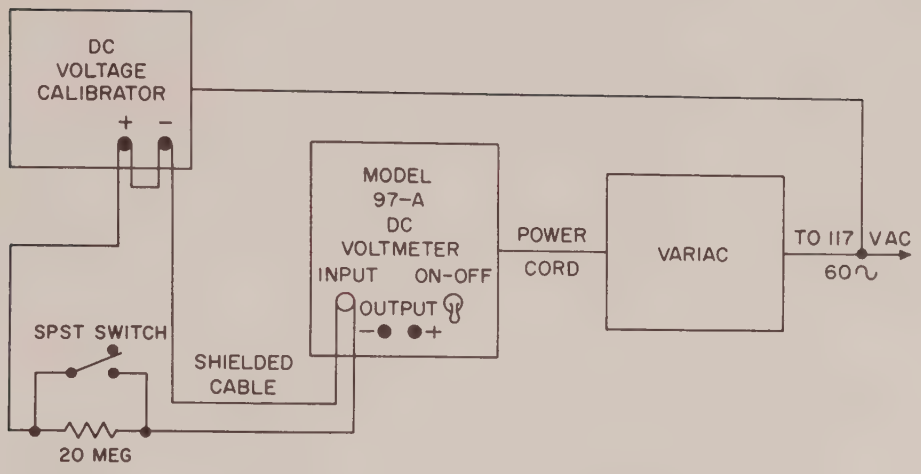


Figure 4-8. Input Impedance Test Setup

d. Turn on power to equipment and allow a five-minute warm-up.

e. Set the meter to read zero, using the ZERO control.

f. Observe the meter reading for a period of five-minutes. On a normal meter, the change from zero should not be appreciably more than 1.0 percent of full scale. (Maximum allowable is 3.0 percent.)

4-25. INPUT IMPEDANCE TEST. If specified accuracies were obtained when testing as detailed in paragraph 4-23, the input impedance of the Model 97-A was simultaneously proven. However, if it is desired to check the input impedance separately, the following procedure may be used.

a. Set up equipment as in figure 4-8.

b. Turn on power to all equipment and allow to stabilize for 30 minutes.

c. With 20 megohm resistor bypassed by spst switch, set RANGE-FULL SCALE switch on Model 97-A to 1 MILLIVOLTS position, and apply 1.0 millivolt from the d-c voltage calibrator.

d. Read and record voltage on Model 97-A. Label this voltage A.

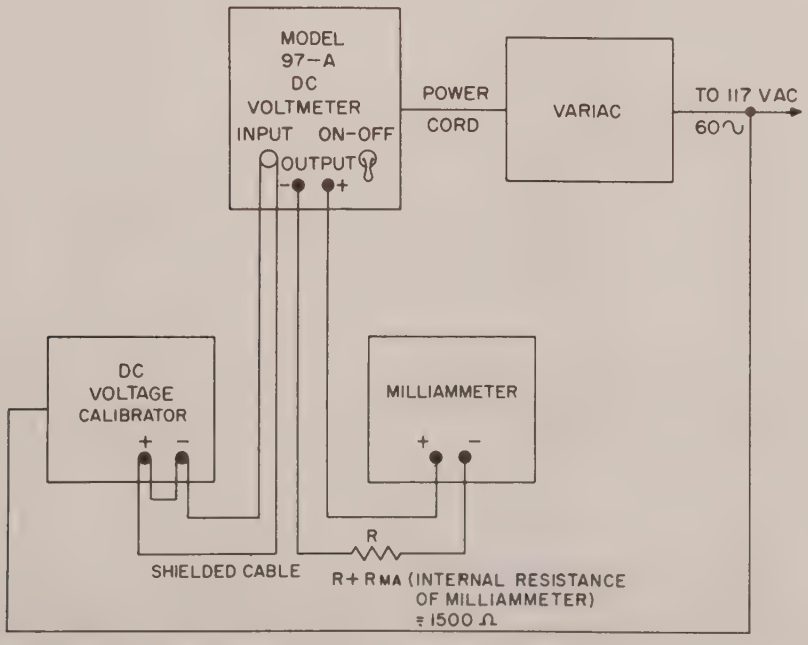


Figure 4-9. Amplifier Output Performance with 1500 Ohm Load Test Setup

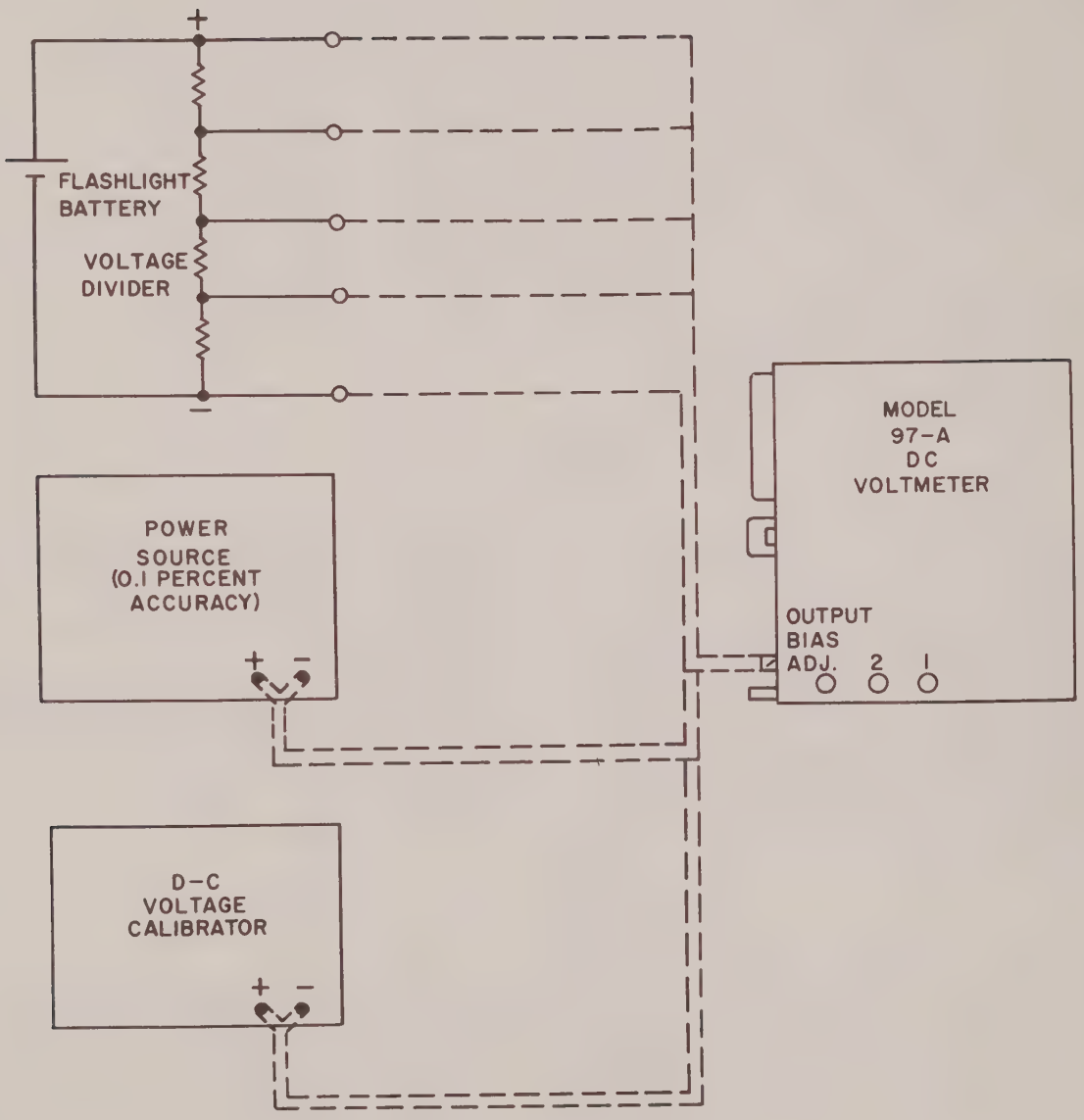


Figure 4-10. Calibration Setup

e. Switch 20 megohm resistor into circuit. Read and record the voltage on Model 97-A. Label this voltage B.

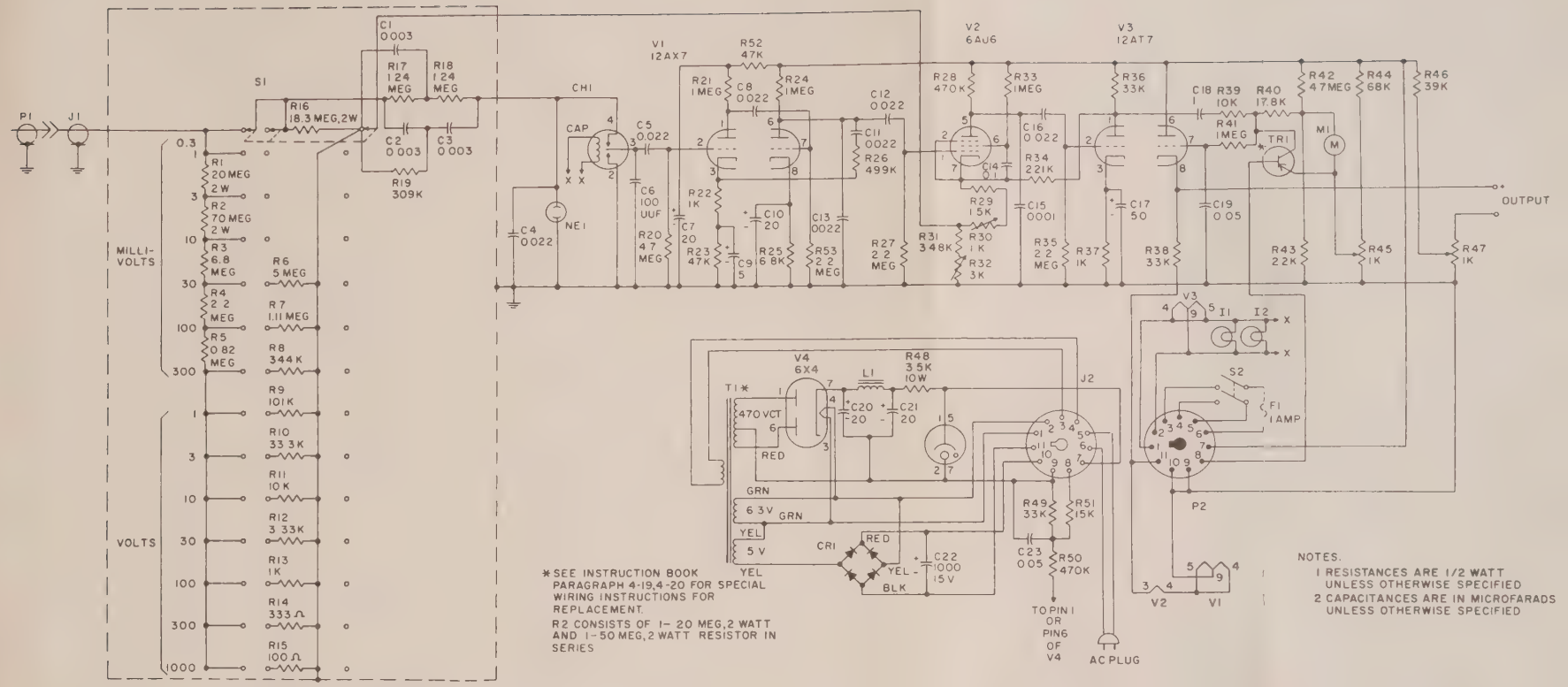
f. Calculate input impedance from the following formula.

$$\text{Input Impedance (Megohms)} = \frac{B}{A-B} \times 20$$

g. Repeat steps c through f for the 3 and 10 MILLIVOLTS positions of the RANGE-FULL SCALE switch, applying corresponding voltages from the d-c voltage calibrator. The input impedance should calculate approximately to the following values.

INPUT VOLTAGE RANGES	APPROXIMATE INPUT IMPEDANCE
0.3 and 1.0 mv	10 Megohms
3.0 mv	30 Megohms
10 mv to 1000 v	100 Megohms

4-26. AMPLIFIER OUTPUT PERFORMANCE TEST (1500 OHM LOAD). To check the performance of the amplifier output under a 1500-ohm load, proceed as follows.



*SEE INSTRUCTION BOOK PARAGRAPH 4-19, 4-20 FOR SPECIAL WIRING INSTRUCTIONS FOR REPLACEMENT.

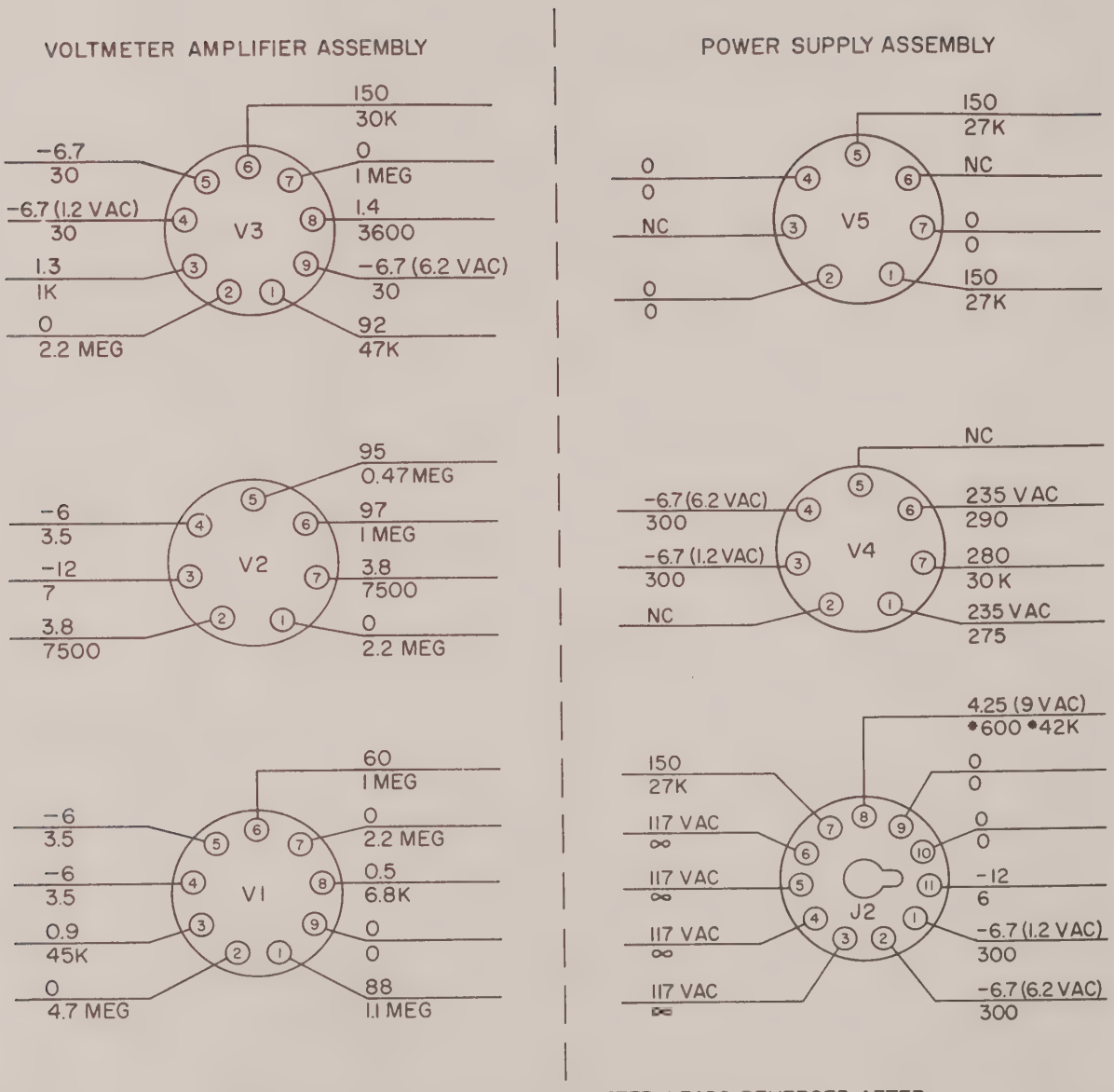
R2 CONSISTS OF 1- 20 MEG, 2 WATT AND 1- 50 MEG, 2 WATT RESISTOR IN SERIES

NOTES.

1 RESISTANCES ARE 1/2 WATT UNLESS OTHERWISE SPECIFIED

2 CAPACITANCES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED

Figure 4-11. DC Voltmeter-Amplifier Model 97-A, Overall Schematic Diagram



•-MEASURED WITH 20,000 OHM/VOLT METER, LEADS REVERSED AFTER FIRST MEASUREMENT. MEASUREMENTS ARE APPROXIMATE.

NOTES:

1. TUBE SOCKET LOCATIONS SHOWN ARE BOTTOM VIEWS.
2. VOLTAGES ARE TOP OF LINE, RESISTANCES BOTTOM.
3. VOLTAGES ARE DC UNLESS OTHERWISE NOTED.
4. RESISTANCES ARE IN OHMS UNLESS OTHERWISE NOTED.
5. D-C VOLTAGES AND RESISTANCES ARE MEASURED BY 20,000 OHM/VOLT METER.
6. A-C VOLTAGES ARE MEASURED WITH VTVM.
7. ALL MEASUREMENTS MADE FROM PIN TO CHASSIS, CHASSIS INTERCONNECTED.
8. ZERO CONTROL AND RANGE-FULL SCALE SWITCH FULLY CLOCKWISE.

Figure 4-12. Voltage and Resistance Measurements

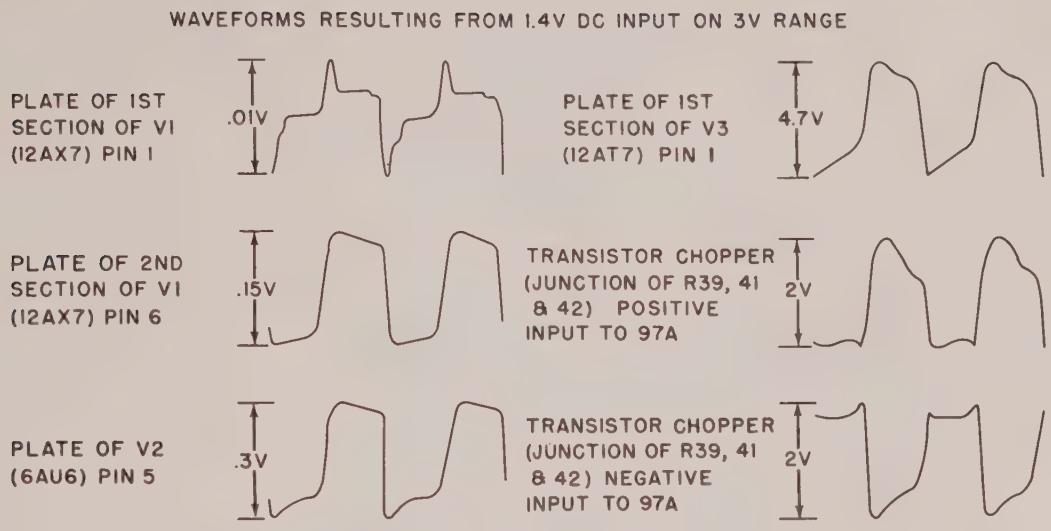

WAVEFORMS RESULTING FROM 1.4V DC INPUT ON 3V RANGE
PLATE OF 1ST SECTION OF V1 (12AX7) PIN 1
.01V
PLATE OF 1ST SECTION OF V3 (12AT7) PIN 1
4.7V
PLATE OF 2ND SECTION OF V1 (12AX7) PIN 6
.15V
TRANSISTOR CHOPPER (JUNCTION OF R39, 41 & 42) POSITIVE INPUT TO 97A
2V
PLATE OF V2 (6AU6) PIN 5
.3V
TRANSISTOR CHOPPER (JUNCTION OF R39, 41 & 42) NEGATIVE INPUT TO 97A
2V

Figure 4-13. Waveform Diagram

a. Set up equipment as in figure 4-9.
b. Turn on power to all equipment and allow to stabilize for 30 minutes.
c. Set RANGE-FULL SCALE switch on Model 97-A to 1 MILLIVOLTS position and zero the meter using the ZERO control.
d. Adjust OUTPUT BIAS ADJ. control on the Model 97-A so that the milliammeter reads zero milliamperes.
e. Apply voltages from d-c voltage calibrator in steps of 0.2 mv from 0.2 to 1.0 mv. Read and record milliammeter indications. Amplifier output should rise in steps of approximately 0.13 ma.
f. Reverse the leads at the milliammeter and d-c voltage calibrator.
g. Repeat steps c through e.

4-27. CALIBRATION PROCEDURE.

4-28. Calibration of the Model 97-A can be performed in a few simple steps, as described below. However, the procedure must be followed exactly as outlined, or incorrect calibration will result.

4-29. The calibrating source can be any voltage source whose accuracy is known, and which lies between 0.1 percent and 1.0 percent. For field calibration, a fresh flashlight battery (1.56-volt output) and a voltage divider composed of 1.0 percent resistors will be of sufficient accuracy. For laboratory calibration it is preferred that a known voltage source with an accuracy of 0.1 percent or better be employed. If this source is unavailable, the d-c voltage calibrator employed in the test procedures already described may be utilized as the voltage source.

4-30. To calibrate the Model 97-A, proceed as follows.
a. Set up equipment as in figure 4-10, depending on voltage source employed.
b. Turn power on to all equipment and allow to stabilize for 30 minutes.
c. Set RANGE-FULL SCALE switch on Model 97-A to .3 MILLIVOLTS position.
d. With zero output from voltage source, and with input cable clips shorted together, zero the Model 97-A using the ZERO control.
e. Adjust voltage source to provide 0.3 millivolt output.
f. Adjust the 1 control on the side of the Model 97-A so that the pointer on the meter reads exactly full scale (3).
g. Recheck ZERO as in step d; reset if necessary.
h. Recheck full scale reading with 0.3 mv input. If necessary, repeat step f.
i. Reverse the leads from the voltage source and read the indication on the Model 97-A. If the reading is nominal, no further adjustment of the 1 control is required. However, if the indication of the two polarities differ, readjust the 1 control so that the average of the two readings is nominal (i.e. 0.3 mv in this instance).
j. Repeat steps c through i for the 1.0 millivolt range of the Model 97-A, using a 1.0 mv source and adjusting the 2 control. This completes calibration.

SECTION V

PARTS LIST

MODEL 97-A DC VOLTMETER-AMPLIFIER

MAJOR UNIT: DC Voltmeter Assembly - Part No. BEC-097001

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
	097002	CASE ASSEMBLY	
	097009	INPUT CABLE ASSEMBLY	
	097004	PANEL ASSEMBLY	
	COML	SCREW, machine, 6-32 x 3/8 in. lg,binding hd, br, black nickel plate	
	COML	SCREW, machine, 8-32 x 3/8 in. lg, binding hd, br, black nickel plate	

MAJOR UNIT: Case Assembly - Part No. BEC-097002

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
	600101	CASE	
	782112	DECAL (Meyercord)	
	757502	FOOT, rubber (Atlantic India Rubber Co. No. 1343)	
	796100	HANDLE (National PH-1)	
	780101	NAMEPLATE	
	097003	POWER SUPPLY ASSEMBLY	
	COML	SCREW, machine, 6-32 x 3/8 in., binding hd, br, black nickel plate	

MAJOR UNIT: Power Supply Assembly - Part No. BEC-097003

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
	810005	BUSHING, strain relief (HEYCO-SR-5P)	
C20, C21	283100	CAPACITOR, electrolytic, 20 x 20 uf x 450 vdc (Mallory FP-234)	

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
C22	283101	CAPACITOR, electrolytic, 1000 mf x 15 vdc (Mallory WP-039)	
C23	230111	CAPACITOR, paper, 0.05 mf ± 10%, 200 vdcw (Aerovox P82)	
	601103	CHASSIS	
L1	440001	CHOKE (Stancor C1707)	
	810010	CLAMP, cable (Commercial Plastics Corp. No. 1953-6B)	
	568100	LINE CORD, 6 in. lg, (Royal SVO w/MP-1)	
	720002	PLATE, capacitor mtg (Mallory BP-4)	
CR1	532001	RECTIFIER, Selenium (FTR 1016)	
R50	301029	RESISTOR, 470000 ohms ± 10%, 1/2 w (Allen-Bradley EB)	
R51	301115	RESISTOR, 15000 ohms ± 5%, 1/2 w (Allen-Bradley EB)	
R49	301123	RESISTOR, 33000 ohms ± 5%, 1/2 w (Allen-Bradley EB)	
R48	312102	RESISTOR, 3500 ohms ± 10%, 10 w (Ohmite Brown Devil)	
XV4, XV5	472100	SOCKET, electron tube, 7 pin miniature (Cinch 7EM)	
J2	472101	SOCKET, 11 pin (Amphenol No. 77-MIP-11)	
	491001	TERMINAL STRIP (Cinch 1520A)	
T1	446000	TRANSFORMER, power (Stancor PC-8401)	
V5	5260A2	TUBE, electron, type 0A2	
V4	5266X4	TUBE, electron, type 6X4	

MAJOR UNIT: Panel Assembly - Part No. BEC-097004

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
	097005	AMPLIFIER ASSEMBLY	
	700132	COVER, (MF 700130) (HU-325C-1)	
F1	545500	FUSE, 1 amp (BUSS AGC-1)	
	482100	FUSEHOLDER (BUSS HKP)	
	775108	KNOB (Raytheon No. 125-3-2)	

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
	775114	KNOB (Davies No. 1400)	
I1, I2	545102	LAMP, No. 51 p/o part no. 554111	
	500103	LUG, turret (CTC 1724C)	
M1	554111	METER (Phaostron No. SPECIAL 100-0-100 ua)	
	602110	PANEL	
	740108	POST, binding (Grayhill No. 29-3B)	
J1	479116	RECEPTACLE (Amphenol No. 80C)	
R45	311111	RESISTOR, variable, 1000 ohms ± 20%, w/1 in. slotted, shaft, incl bushing (Ohmite CU-1027)	
	700131	SHIELD	
	742038	SPACER, hex, 1/4 x 1 in. lg, 8-32 thd, br, cadmium plate (H.H. Smith No. 2329)	
	602119	SUB-PANEL	
	097006	SWITCH ASSEMBLY	
	465100	SWITCH, toggle, dpst (Carling No. 216-62)	
TB3	486108	TERMINAL BOARD, meter	

MAJOR UNIT: Amplifier Assembly - Part No. BEC-097005

Reference Designation	Boonton Electronics Part No.	Description	Stock No.
NE-1	545102	BULB, neon, 1/25 watt (GE NE-2)	
	COML	CABLE, microphone cable (Belden No. 8401)	
C15	201117	CAPACITOR, mica, 0.001 mf ± 20% (MIL type CM20B102M)	
C6	201119	CAPACITOR, silver mica, 100 mmf ± 10% (MIL type CM20C101K)	
C4, C5, C11, C12, C13, C16	230101	CAPACITOR, paper, 0.022 mf ± 20%, 200 vdcw (Good-All 620M22302)	
C14	230103	CAPACITOR, paper, 0.1 mf ± 20%, 200 vdcw, (Aerovox P-82 Aerolite)	
C18	230104	CAPACITOR, paper, 1.0 mf ± 20%, 200 vdcw (Aerovox P-82 Aerolite)	
C7, C10, C17	283109	CAPACITOR, electrolytic, 20 mf x 475 vdc, 50 mf x 50 vdc, 20 mf x 25 vdc, (Mallory FP3791)	
	601104	CHASSIS	

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
CH1	540102	CHOPPER, spdt, break-before-make, (Stevens-Arnold A-12)	
	COML	GROMMET, used on part no. 812002 (p/o Amphenol 11-3K Kit)	
	792104	GROMMET, live rubber, used on part no. 472102 (p/o Amphenol 11-3K Kit)	
	792105	GROMMET, for 3/8 in. hole (General Cement No. 1042)	
	792106	GROMMET, for 5/16 in. hole (General Cement No. 1041)	
	792107	GROMMET, used with part no. 604008 (Minor Rubber No. S4552) (AN931-14-20)	
	604008	HOLDDOWN, chopper	
	602102	PLATE, bottom	
	720002	PLATE, capacitor mtg (Mallory BP-4)	
	477105	PLUG, 11-pin (Amphenol No. 86-PM-11-11)	
R25	301018	RESISTOR, 6800 ohms ± 10%, 1/2 w (Allen-Bradley EB)	
R28	301029	RESISTOR, 470000 ohms ± 10%, 1/2 w (Allen-Bradley EB)	
R22, R37	301087	RESISTOR, 1000 ohms ± 5%, 1/2 w (Allen-Bradley EB)	
R21, R24, R33	301159	RESISTOR, 1.0 megohm ± 5%, 1/2 w (Allen-Bradley EB)	
R27, R53, R35	301167	RESISTOR, 2.2 megohms ± 5%, 1/2 w (Allen-Bradley EB)	
R20	301175	RESISTOR, 4.7 megohms ± 5%, 1/2 w (Allen-Bradley EB)	
R31	306304	RESISTOR, 3480 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R34	306520	RESISTOR, 221000 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R26	306562	RESISTOR, 499000 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R30	311100	RESISTOR, variable, 1000 ohms ± 20% linear (IRC 34-1610-7395)	
R32	311112	RESISTOR, variable, 3000 ohms ± 20% linear (IRC RQ 11-112)	
R47	311113	RESISTOR, variable, 1000 ohms ± 20% slotted 1 in. shaft (IRC PQ 11-108)	
	COML	SCREW, machine, 6-32 x 1/4 in., binding hd, br, nickel plate	

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
	812002	SHIELD, electron tube (ELCO TS103U02)	
	730115	SHIELD, input	
	812001	SHIELD BASE (Cinch 9SB1)	
XV2	472110	SOCKET, electron tube, 7 pin miniature (Cinch 53C13984)	
XV1,XV3	472111	SOCKET, electron tube, 9 pin miniature (Cinch 44C12827)	
	472102	SOCKET, octal, chopper, (Amphenol 77-MIP-8FK)	
	742039	STANDOFF, used on part no. 601104 (CTC 1246C-3/8)	
	097007	TERMINAL BOARD No. 1 ASSEMBLY	
	097008	TERMINAL BOARD No. 2 ASSEMBLY	
V3	52612AT7	TUBE, electron, type 12AT7	
V1	52612AX7	TUBE, electron, type 12AX7	
V2	5266AU6	TUBE, electron, type 6AU6	

MAJOR UNIT: Switch Assembly - Part No. BEC-097006

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
C1,C2,C3	203001	CAPACITOR, silver mica, 0.003 uf ± 1%, (MIL type CM30C or D)	
R5	301157	RESISTOR, 0.82 megohm ± 5%, 1/2 w (Allen-Bradley EB)	
R4	301167	RESISTOR, 2.2 megohms ± 5% 1/2 w (Allen-Bradley EB)	
R3	301179	RESISTOR, 6.8 megohms ± 5%, 1/2 w (Allen-Bradley EB)	
R15	306120	RESISTOR, 100 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R13	306239	RESISTOR, 1000 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R11	306359	RESISTOR, 10000 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R19	306537	RESISTOR, 309000 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R17,R18	306607	RESISTOR, 1.24 megohms ± 1%, 1/2 w (Aerovox CPS 1/2)	

Reference Designation	Boonton Electronics Part No.	Description	Stock No.
R7	306687	RESISTOR, 1.11 megohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R8	306688	RESISTOR, 344000 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R9	306689	RESISTOR, 101000 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R10	306690	RESISTOR, 33300 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R12	306691	RESISTOR, 3300 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R14	306692	RESISTOR, 333 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R6	306693	RESISTOR, 5 megohms ± 1%, 1/2 w (Aerovox CP 1/2)	
R1, R2A	308722	RESISTOR, 20 megohms ± 1%, 2 w (Aerovox CP 2)	
R2B	308723	RESISTOR, 50 megohms ± 1%, 2 w (Aerovox CP 2)	
R16	308724	RESISTOR, 18.3 megohms ± 1%, 2 w (Aerovox CP 2)	
S1	466109	SWITCH (Oak DLX SPECIAL 18 Point)	

MAJOR UNIT: Terminal Board No. 1 Assembly - Part No. BEC-097007

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
C19	230117	CAPACITOR, paper, 0.05 mf ± 10%, 200 vdcw (Aerovox P82)	
	500103	LUG, turret (CTC 1724C)	
R43	301021	RESISTOR, 22000 ohms ± 10%, 1/2 w (Allen-Bradley EB)	
R44	301024	RESISTOR, 68000 ohms ± 10%, 1/2 w (Allen-Bradley EB)	
R42	301035	RESISTOR, 4.7 megohms ± 10%, 1/2 w (Allen-Bradley EB)	
R38	301099	RESISTOR, 3300 ohms ± 5%, 1/2 w (Allen-Bradley EB)	
R41	301159	RESISTOR, 1 megohm ± 5%, 1/2 w (Allen-Bradley EB)	
R46	302139	RESISTOR, 39000 ohms ± 5%, 1 w (Allen-Bradley GB)	
R29	306261	RESISTOR, deposited carbon, 1500 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
R39	306359	RESISTOR, 10000 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
R40	306388	RESISTOR, 17800 ohms ± 1%, 1/2 w (Aerovox CPS 1/2)	
	742039	STANDOFF (CTC 1246C-3/8 in.)	
TB1	486105	TERMINAL BOARD	
TR1	528001	TRANSISTOR (Sylvania type 2N34)	

MAJOR UNIT: Terminal Board No. 2 Assembly - Part No. BEC-097008

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
C9	283108	CAPACITOR, electrolytic, 5 uf x 6 v dc (Cornell-Dubilier BBR 5-6)	
	500103	LUG, turret (CTC 1724C)	
R36	301123	RESISTOR, 33000 ohms ± 5%, 1/2 w (Allen-Bradley EB)	
R23, R52	301127	RESISTOR, 47000 ohms ± 5%, 1/2 w (Allen-Bradley EB)	
	742022	STANDOFF (CTC 1246C-1/4 in.)	
TB2	486101	TERMINAL BOARD	

MAJOR UNIT: Input Cable Assembly - Part No. BEC-097009

Reference Designation	Boonton Electronics Part Number	Description	Stock No.
	COML	CABLE, 4 ft lg (Amphenol No. 21-537)	
	483106	CLIP, ground, black (Industrial Devices SAFE-T-CLIP No. 1410A-1)	
	483107	CLIP, red, (Industrial Devices SAFE-T-CLIP No. 1410B-2)	
P1	477112	CONNECTOR (Amphenol No. 80-M)	
	571004	PROBE, red, (H. H. Smith No. 302)	
	COML	WIRE, black, 4 ft lg, No. 20 flexible test prod. (Alpha No. 1633 black)	

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